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Study of the time evolution of magnetic turbulence induced by the magneto-rotational instability

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Magneto-rotational instability (MRI) is thought to be the generation mechanism of turbulence in accretion disks. Since the resultant turbulence stress causes the angular momentum transport and mass accretion, it is necessary to understand the processes determining the saturation level of the turbulent stress. Sai et al. (2013) suggested that the time variation of MRI turbulence is determined by the existence of the poloidal component of background magnetic field. In the nonzero net poloidal flux case, spike shape time variation of turbulent stress is observed and is suggested to contribute to large part of turbulent stress (e.g., Sano and Inutsuka, 2001). However, details of the physical processes have not been analyzed in the previous studies.

We investigate the processes occurring on the MRI turbulence by performing three-dimensional magnetohyrdodynamic simulations. Our study reveals the most part of processes in the nonlinear state of MRI. Specifically, our simulations reveal the existence of characteristic mode which has the largest amplitude in the nonlinear state of MRI. In this presentation, we report the characteristics of the largest amplitude mode and relaxation process in MRI turbulence.

Based on the results of analysis, we find that the observed dominant mode is expected to be the same wave mode which causes the channel flow reported in Sano and Inutsuka (2001). In previous studies, this mode is thought to be caused by the fastest growing mode which is lengthened by amplification of energy from poloidal magnetic field in turbulence (e.g., Sano and Inutsuka, 2001). However, from detailed analysis, although this mode is explained by the dispersion relation of MRI, we clarify that the wave pattern is determined by the disk thickness and the poloidal component of background field rather than the poloidal component of turbulence. This suggests that the determination process of the largest amplitude mode in the nonlinear state is different from the understanding of the previous studies. In saturation and relaxation phases of this mode, the generation of the parasitic instability (Goodman & Xu, 1994) is suggested even in the nonlinear state. From detailed estimation of each term in the MHD equation system, we also succeed to derive the condition for the occurrence of the relaxation. Using this relaxation condition, it is suggested that the amplification of the poloidal component of magnetic field is crucial to onset of turbulent relaxation. This amplification of the poloidal component of field is also expected to be caused by the growth of the parasitic instability. Moreover, the determination manner of the wave length of dominant mode can be explained by the relaxation condition.

Based on our findings, it is consistently explained that the energy ratio between the radial and azimuthal components of magnetic field, which has been reported in the previous simulations (e.g., Hawley et al., 1995) but has been unsolved. The obtained relation means that the field structure on the turbulence can be predicted when the poloidal flux of background field is given. We expect that the net flux dependence of the turbulent property revealed by the present study becomes a strong tool for considering the coagulation of dust particle and estimating the effect of MRI on disk turbulence.

Keywords: accretion disk, magnetohydrodynamics, turbulence, magneto-rotational instability